Survey of DMSP Charging During the Period Preceding Cycle 24 Solar Maximum

L. Neergaard Parker
Jacobs Technology, ESSA Group, MSFC, Huntsville, AL

Joseph I. Minow
NASA, Marshall Space Flight Center, Huntsville, AL

Abstract

It has been well established that polar orbiting satellites can see mild to severe charging levels during solar minimum conditions (Frooinks and Sojka, 1992, Anderson and Koons, 1996, Anderson, 2012). However, spacecraft operations during solar maximum cannot be considered safe from auroral charging. Recently, we have seen examples of high level charging during the recent approach to solar maximum. We present here a survey of charging events seen by the Defense Meteorological Satellite Program (DMSP) satellites (F16, F17) during the solstices of 2011 and 2012. In this survey, we summarise the condition necessary for charging to occur in this environment, we describe how the lower than normal maximum conditions are conducive to the environment conditions necessary for charging in the polar orbit, and we show examples of the more extreme charging events, sometimes exceeding 1 kV, during this time period. We also show examples of other interesting phenomenological events seen in the DMSP data which are not considered surface charging events, and discuss the differences.

Conditions Needed for Auroral Charging

1. Satellite is in darkness
2. An intense, energetic electron (> 14 keV population) precipitation event is required (E > 10^9 electrons cm^-2 s^-1 sr^-1)
3. Locally depleted (< 10^4 cm^-3) ambient plasma density

Surface Charging Physics

Surface charging is the result of a current balance on the surface of a spacecraft. Charging is described by the time dependent current balance relation

\[ \frac{dQ}{dt} = C \left( V - \phi \right) \]

where \( Q \) is the total charge and \( C \) the capacitance of the area \( A \), and \( V \) the voltage of the area. The currents of importance to surface charging are: incident ions, incident electrons, backscattered electrons, conduction currents, secondary electrons, photoelectrons, and active current sources (beams, thrusters).

Auroral charging is readily identified from the “ion line” signature that appears in ion electrostatic analyzer records. The ion line is the result of ambient low energy ions accelerated by the spacecraft potential from an initial energy \( E_0 \approx 0 \) eV to a final energy \( E = E_0 + q \) eV where \( q \) is the charge of the ion and \( \phi \) the spacecraft surface potential in volts.

Event Criteria

1. At least 3 seconds
2. At least -30 V peak
3. Distinguishable ion line, no underlying structure

Discussion and Summary

The examples shown here are the result of an initial effort to characterize extreme auroral charging events. These events are encountered infrequently by spacecraft in polar low earth orbit but are the kind of event that drive spacecraft design. We have focused on the extreme potentials, durations the potentials exceed a threshold value, and mean potentials because the information is needed by spacecraft designers for evaluating the response of the spacecraft to the charging environment. Generally, auroral charging events are seen predominantly during solar minimum conditions. However, we have seen charging events of nearly -1000 V in the approach to solar maximum conditions due to the lower than average solar activity in Solar Cycle 24. We focus this study on the solstices (May - July, 2012 and Nov, 2011 - Jan, 2012) because of the larger likelihood of encountering charging events.

- Temporal variations of the spacecraft potential through a charging event are important since extreme potentials are generally only a subset of the charging event,
- Frame potentials may reach kilovolt levels in auroral charging environments, but the duration of charging at these most extreme levels are limited to periods of a few seconds to perhaps ten to fifteen seconds,
- Mean potentials over the period of a charging event never exceed a few hundred volts,
- Rise time of the spacecraft potential is generally rapid for the events, with a slower time to decrease back to equilibrium.

Future work is planned to expand the study to a wider range of charging events to more fully characterize the auroral charging environment for this solar maximum period. A paper to Geophysical Research Letters is in work.